BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: ATM Alternate Mission Study Summary - Case 620

DATE: September 6, 1968

FROM: G. M. Anderson

ABSTRACT

Alternate missions were studied with durations of 28 and 56 days at inclinations of 28 1/2°, 50° and 63.5°. The CM-SM and LM-ATM are launched separately and rendezvous and dock in orbit. Attitude control is with the CMG system on the LM-ATM.

Both circular and elliptical orbits were studied. Elliptical orbits are of advantage only around the June solstice. They offer continuous solar viewing for up to 5 days over a 280 km atmosphere.

Missions of 28 days duration at i = 50° using continuous crew rotation scheduling can essentially meet the ATM experiment requirements. Major system changes are not required.

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: ATM Alternate Mission Study Summary - Case 620

DATE: September 6, 1968

FROM: G. M. Anderson

MEMORANDUM FOR FILE

INTRODUCTION

This report presents the results of a brief study of alternate missions for the AAP solar astronomy mission, usually referred to as the ATM* Mission. Alternate missions, as used here, are a special case of ATM contingency missions in which the decision not to cluster the Orbital Workshop, LM-ATM, and CM-SM is made prior to the launch of both the latter two spacecraft. In this case freedom exists to vary the mission parameters to optimize the expected scientific yield.

The purpose of the study was to:

(a) develop ATM Mission alternatives to the baseline Cluster Mission for the eventuality that the latter mission cannot be flown,

(b) compare the expected scientific yield with the Cluster Mission, and

(c) identify additional system requirements for the alternatives considered.

AREAS OF STUDY

The study covered the following topics:

Spacecraft Weight
Performance Analysis
Solar Viewing
Scientific Yield
Attitude Control
Electrical Power
Structures
Radiation Dose Levels for Men and Film
Computer Systems Impact
Tracking and Communication Coverage.

---

* Apollo Telescope Mount.

Memoranda on these subjects follow this summary in the order indicated. This summary contains, in addition, a brief review of a Martin Marietta Corporation study of ATM Experiment scheduling (Ref. 1) plus the conclusions of the current study.

ASSUMPTIONS AND CONDITIONS

The orbital configuration employs separately launched CM-SM and LM-ATM spacecraft docked on the axis of symmetry (x axis). The mission is flown with the symmetry axis aligned with the solar vector. Stabilization and control are achieved with the control moment gyro system (CMG) on the LM-ATM as in the baseline Cluster Mission. While this attitude is non-optimum from the standpoint of bias momentum accumulation in the CMG system it is the only possible orientation given the current hardware.

The following assumptions and conditions were employed:

1. Saturn I-B launch system.

2. Mission Duration. Three cases initially specified, 14 days, 28 days, and 56 days. The 14 day case was dropped from consideration since it is unacceptable from the scientific yield standpoint.

3. AAP Standard CM-SM

   (a) Average Power Level of 2.8 KW. LM-ATM electrical power system supplies 1 KW to the CM-SM.

   (b) Weight - As detailed in the weight memorandum.

4. LM-ATM

   (a) LM-A Baseline.

   (b) Primary battery capacity - Retain LM-A baseline Program Requirements Review (PRR) configuration of 30 Kwhr.

   (c) Weight - As detailed in the weight memorandum.

5. Mission Mode

   (a) LM-ATM launch is first.

   (b) No solar array deployment prior to CM-SM docking.

   (c) CM-SM Launch to Orbit - Two cases:
   (i) S-IB insertion
   (ii) SPS suborbital thrusting maneuver.

   (d) Rendezvous in low earth orbit.

   (e) SPS thrusting maneuver(s) to final orbit.

   (f) RCS Backup deorbit capability is required.

6. Duration and Orbital Parameters

   Table I summarizes the cases examined and indicates which require the use of the SPS suborbital thrusting maneuver.

SUMMARY OF RESULTS

1. Performance Analysis

   (a) High Inclination Orbits - Missions of 28 days duration are possible at 50^{o} inclination without the 2 1/2 stage to orbit* capability and without yaw steering of the launch vehicle.** Only northerly launches are possible.

   Missions of 28 days at 63.5^{o} inclination and 56 days at 50^{o} inclination require 2 1/2 stages to orbit capability. The 63.5^{o} inclination requires, in addition, yaw steering of the S-IVB stage.

---

* 2 1/2 stages to orbit is a program description for SM SPS suborbital thrusting.

** A tentative conclusion with respect to yaw steering. Range approval for the launch profile requires detailed mission planning and complete impact point dispersion analysis.

Duration and Orbital Parameters

Duration Days	Inclination Degrees	Altitude N.M.	2-1/2 Stage to Orbit
56 (Cluster)	28-1/2	230x230	No
28	28-1/2	230x230	No
56	50	150x400	Yes
28	50	150x400	No
28	50	150x600	Yes
28	50	375x375	Yes
28	63.5	150x300	Yes
28	63.5	225x225	Yes

150 NM perigee determined by rendezvous considerations. Apogee and circular altitudes based on vehicle performance limits.

Table I

(b) Mission Mode - The LM, launched first, is inserted into an 80 x 150 n. mi. orbit and circularized at 150 n. mi. with the RCS system. The CM-SM is inserted into a lower altitude orbit, for phasing reasons, 1 to 4 days later. After rendezvous the SPS is used to obtain final orbit. The apogee of elliptical orbits may be located without constraint. Normal return from elliptical orbit is to circularize with the SPS followed by a second burn for control of touchdown. Backup deorbit uses RCS burn at apogee.

(c) Rendezvous in a high inclination orbit may require up to 3 days for phasing.

2. <u>Solar Viewing</u>

(a) The effect of inclination on total solar viewing time for circular orbits of the same altitude is not large.* The increased inclination adds, at most, 10-15% to the total solar viewing time.

(b) Elliptical orbits do not increase total solar viewing time appreciably when compared with the corresponding circular orbit.** Example: 28 day missions, June solstice launch, $i = 50^{\circ}$, 150 x 400 n. mi. gives 478 hrs., 300 x 300 n. mi. gives 465 hrs.

(c) Elliptical orbits enhance continuous solar viewing time. Example: 28 day missions, June solstice launch, $i = 50^{\circ}$, 400 x 150 n. mi. gives 5 days, 300 x 300 n. mi. gives 0 days.

(d) Elliptical orbits are only of utility for missions launched near the June solstice. The advantages are continuous solar viewing for several days and less radiation dose than the comparable circular orbit.

---

* The $i = 28.5^{\circ}$ case is penalized somewhat in this comparison. Launch vehicle performance margins permit a higher altitude at $28\ 1/2^{\circ}$ inclination but radiation limits may make this option unattractive. The way to take the trade is in increased mission duration, if this is feasible.

** Corresponding orbits in this memorandum implies using the launch vehicle to its performance limit given the requirements appropriate to the orbits and the duration.

(e) Earth horizon (280 km atmosphere) - sun line angles are acceptable for the coronograph experiment.

(f) Maximum solar viewing at June solstice requires a night time launch.

3. Scientific Yield

(a) Duration is the most significant parameter. The 56 day cluster mission is preferable to a 28 day alternate mission.

(b) Probability of flare detection is improved at high inclination 50° or 63.5° over 28.5° as a consequence of longer solar viewing time (.78 vs. .71).

(c) There is a premium on early launch because of the decreasing solar activity in this time period.

4. Attitude Control

No major problems are foreseen in controlling the CM-SM/LM-ATM with the CMG system. The Pointing Control System should be able to meet the ATM accuracy requirements without change.

The study budgeted 10 lbs. per day RCS propellant for CMG desaturation of bias momentum. This amount is conservative for circular orbits and can be reduced by about 200 lbs. even for the 50° inclination mission if a gravity gradient desaturation method is employed. The elliptical orbit has an additional bias momentum accumulation arising from the aerodynamic torque which has not been fully assessed.* A preliminary estimate of the additional requirement is 150-200 lbs. of RCS propellant.

The star tracker is no longer required for the orbital plane reference but is required for the roll reference as in the cluster configuration. Depending on the roll orientation in the alternate mission there might be a change required in the star tracker location or the gimbal limits. There is one roll orientation, that which aligns the LM-ATM as in the Cluster mission, which requires no change in the star tracker.

---

* We are indebted to Frank Littleton of MSC for this observation.

5. Electrical Power

It is not clear at this time whether, as assumed, the LM-ATM EPS can supply 1 KW of electrical power to the CM-SM on a mission average basis. It is clear that less than 1 KW is available at $\beta = 0^{o}$. The figure is probably more nearly 400-500 watts. The problem is battery temperature which limits the power level to 200 watts per battery or 3600 watts for the system out of 3900 watts which should be available. Increased power should be available at higher β angles. The MSFC study of the thermal problem on the batteries as a function of β is not complete.

Provided it is possible to utilize the increased solar power available at higher β angles, the high inclination missions offer more potential in this regard than the 28.5^{o} inclination missions.

6. Structures

No new problems are anticipated.

7. Radiation Dose Levels

There does not appear to be a radiation problem for the crew on the alternate missions studied. Film fogging does appear to pose a difficulty and may lead to a requirement for shielding if the film is stored in the LM.

Elliptical Orbits with perigee constrained to the southern hemisphere have less radiation exposure than the corresponding circular orbit. The comparison for the LM is roughly 25 RADS vs. 50 RADS for a 28 day mission. Radiation dose level limits proposed for the ATM film range from 10 to 20 RADS.

8. Computer Systems Impact

Present ground and spacecraft systems appear adequate to support the alternate missions studied.

9. Tracking and Communication Coverage

Launch coverage for 50^{o} and 63.5^{o} inclined orbits will require two tracking ships.

Network coverage* during the mission is not a strong function of inclination. VHF coverage drops from 27.2% at 230 x 230 n. mi., i = 28.5° to 20.9% at 150 x 400 n. mi., i = 50° and UHF coverage drops from 29.4% to 27.4%.

10. ATM Experiment Scheduling

A Martin Marietta Corporation (MMC) report of ATM experiment scheduling (Ref. 1) has become available since this study was completed. The results are useful here and a brief summary is in order.

ATM Experiment Requirements

These are separated into prime time and rider time requirements. Total requirements are the sum of the two. Concurrent operation of experiments is necessary in all cases to obtain experiment time commensurate with the requirements. MMC projections indicate 329 hours prime time and 305 hours of rider time are required.

Prime Time

This is time assigned to a particular experiment where its requirements control pointing, stability and duration of attitude hold.

Rider Time

This is time where a particular experiment has requirements which are common with respect to pointing and subordinate with respect to stability and duration to another experiment which is prime at this moment.

Cluster Mission

The 56 day Cluster Mission experiment time exceeds the prime time requirements for the sun centered and flare modes and provides 67.9% and 90.1% of the quiet sun and active offset mode requirements respectively. Rider time provides additional data for all modes. If the prime and rider time requirements are taken together, the Cluster Mission experiment time exceeds requirements in all modes.

---

* % Time in Contact.

Alternate Mission

The alternate mission* studied by MMC utilized a 210 x 210 n. mi., i = 50° orbit. Launch time of 4 A.M., May 15, 1971 was assumed. This date was selected as consistent with the ML-14 schedule. The earth's atmosphere was taken as 120 km.

The time line analysis was done for two crew scheduling conditions:

Usual Procedure - Normal Ground Rules for Crew Scheduling

Continuous Crew Rotation - Continuous manning of ATM experiments.

The analysis shows that continuous crew rotation is necessary to meet the experiment requirements.** For most of the modes, i.e. sun centered, quiet sun, and active offset, the time margins are not great. This implies that optimization of the alternate missions is necessary, since the mission analyzed was near optimum, to fully meet the experiment requirements.

Since the Martin Marietta study used a significantly lower altitude and atmospheric height than the Bellcomm study, the Bellcomm computer program was used to determine total solar viewing time using the Martin-Marietta orbital parameters. The result showed 451 hours for the circular orbit compared with 478 hours for the elliptical orbit used in the Bellcomm study. This conjunction appears to justify, to a first approximation, the conclusions of the MMC time line analysis to the missions studied here.

---

* T. R. Heaton, Martin Marietta Corporation - Verbal Communication.

** Reference 2 tabulates the percentage of prime time and shows less than 100% for the quiet offset (67.9%) and active offset (90.1%) modes using continuous crew scheduling. These percentages are the same as for the Cluster Mission. Adding rider time, as MMC will do in the final report, brings these percentages over the 100% level.

CONCLUSIONS

1. The 56 day Cluster Mission is superior to the 28 day alternate missions in terms of expected scientific yield.

2. Alternate missions can essentially meet the ATM experiment requirements provided continuous crew scheduling is feasible. A high inclination orbit, approximately 50°, and a solstice launch are preferred.

3. Missions with orbital inclination of 50° show 10-15% more total solar viewing time than equal duration missions at 28.5°.

4. Orbital inclination of 63.5° is less effective with respect to total solar viewing time than 50° and requires significant system changes, i.e., 2 1/2 stages to orbit and yaw steering during boost.

5. The elliptical orbit mission, $i = 50^{\circ}$, 150 x 400 n. mi. offers the possibility of 5 days of continuous solar viewing if launched at the June solstice.

6. The way to increase the effectiveness of the alternate missions is to extend duration beyond 28 days.

7. Major system modifications are not required.

   Yaw steering during launch and 2 1/2 stages to orbit are not worth the cost.

   Electrical power may be a problem and requires further study. At worst, and this is not expected, mission duration may be slightly curtailed.

   Shielding of film may be required in the LM.

G. M. Anderson

1022-GMA-ms G. M. Anderson

Attachments.

References

1. Study of ATM Experiment Time Lines, Martin Marietta Corporation, ED-2002-583, July 16, 1968.

2. Ibid., p. 21A